MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

VOL. 55, No. 12
W. B. No. 942

DECEMBER, 1927

CLOSED FEB. 3, 1927
ISSUED FEB. 29, 1928

WINDS AND STORMS ON THE ISTHMUS OF PANAMA

By L. T. CHAPEL, Meteorologist in Charge Hydrographic Office

[Cristobal, Canal Zone, July 14, 1927]

GEOGRAPHICAL POSITION

Introduction.—The geographical position of the Isthmus of Panama is such as to give it practically every variety of wind and storm that occurs within the Tropics. Its location near the thermal equator, and also near the north-south line of displacement between the great wind belts of the Atlantic and the Pacific, bring it successively under the migratory influence of the northeast trades of the Atlantic, the equatorial calm belt, and the southeast trades of the Pacific, or at least, a northward extension of those winds. The general breakdown in the high pressure belt of the horse latitudes to the northward of the Central American Isthmus during the northern summer and autumn makes possible extensive interchange of storms between the two zones, providing an easy avenue of invasion northward by the cyclones of the Tropics, and, later in the year, a return invasion by the cold waves and northers of the Temperate Zone.

The greatest influence on the weather of the Isthmus is exercised by the northeast trades. They usually blow with great steadiness from January to April, inclusive, with occasional extensions into December and May. The duration and general characteristics of the dry season depend upon them.

In June, September, and October of the rainy season, but especially in September and October, a large southerly component is evident in the wind movement over the Isthmus. Sometimes for periods of several days southerly winds will blow with the constancy of, and only slightly less velocity than, the northeast trades. Occasionally they are of sufficient strength and duration to cause heavy seas in Panama Bay.

The migration of the belt of doldrums northward with the sun and its return equatorward brings it over the Isthmus from June to November, inclusive. The trades usually weaken early in May and rainy season conditions become well established before the close of the month.

The trades sometimes resume as early as the first week in December, but usually not until later.

Tropical cyclones do not extend as far south as the Isthmus of Panama, but their appearance in the western Caribbean is frequently attended by pronounced changes in wind and other elements. Heavy rains of a general nature occur near the beginning and also near the end of the rainy season, but the winds accompanying them are usually light. Occasionally a norther occurs this far south.

While many influences are in evidence in the winds at the Isthmus of Panama, the winds themselves and what storms occur are comparatively light. No excessive wind velocities have ever been recorded. The highest for a five-minute period in a 19-year record at Colon is 46 miles from the north. The highest ever recorded on the Isthmus is 59 miles from the south at Balboa Heights. Damage by storms is mostly of a secondary nature, by heavy seas on open coasts and unprotected harbors, or by floods due to excessive and long-continued rains.

WIND RECORDS

Available instrumental records.—Standard United States Weather Bureau equipment, including Robinson cup anemometers, anemoscopes, and automatic registration of simultaneous values of wind direction and velocity, has been in use on the Panama Canal since 1908.[1] Stations have been located at various places along the line of the canal, from Colon, on the Caribbean coast, to Balboa, at the head of Panama Bay. The Colon record is the only one extending over the entire 19-year period, 1908–1926, inclusive, under essentially similar conditions; changes having been made in the location of all the other stations.

During 1919–1922, inclusive, standard Weather Bureau equipment was in use at Cape Mala, at the entrance to Panama Bay and 113 nautical miles almost due south from Colon. Simultaneous values of wind direction and velocity are available for approximately a three-year period.

In addition to the stations maintained by the Panama Canal, meteorological records have been kept in recent years at the Army and Navy aviation fields adjacent to the canal terminals. At the naval air station at Coco Solo, 1¾ miles east-northeast from the Colon weather station, records of pilot balloon flights from 1922 to the present time are available.

Exposure of instruments.—Colon is located on the Caribbean coast, on a coral island, in no place over 10 feet above the level of the sea, and is surrounded by water and mangrove swamps for a distance of about 2 miles. The trend of the coast is northeast-southwest for about 20 miles on each side, giving an open sea exposure from southwest through west and northwest to northeast. On the land side, Gatun Lake lies to the south at a distance of about 7 miles, with an elevation of 85 feet above sea level. To the southeast and east isolated hills reach an elevation of 800 feet at a distance of 7 miles and 2,000 to 3,000 feet at a distance of from 15 to 20 miles. There is no definite valley formation opening on this section of the coast which could effect local winds. Since February, 1917, the exposure of the wind instruments at Colon has been on a skeleton steel tower 97 feet above the ground and about 105 feet above the level of the sea. The location since 1908 has never

[1] A fully equipped first-order station of the United States Weather Bureau was in operation at Colon from September, 1898, to May, 1899.—ED.

(NOTE.—All temperatures are in *Fahrenheit* degrees; wind velocities expressed in *miles per hour.*)

been less than 70 feet above the ground, well overtopping all near-by buildings and trees, and never farther than 200 feet from the beach.

The elevation of exposure of all of the interior stations along the canal is comparatively low, and the instruments of necessity are overtopped by neighboring hills and trees; hence wind conditions are greatly influenced by the trend of the valleys.

The exposure at Balboa Heights is the best obtainable, but it is located in a valley opening on the head of Panama Bay, with ranges of hills on either side rising to an elevation of 1,500 feet or more. About one-fourth mile to the eastward of the station and subtending an angle of about 90° is an isolated hill rising over 300 feet above the anemometer exposure. Short records kept on Sosa Hill, about 1 mile to the southwest of Balboa Heights and near the middle of the valley, show 90 per cent of the dry-season wind and 70 per cent of the rainy-season wind from the northwest and most of the remainder from the southeast. The influence of drainage up and down the valley in the direction of Panama Bay is thus clearly indicated.

All of the stations along the canal, with the exception of Colon, are subject to marked influences by local topography. Colon seems comparatively free of any such influences, but, on those comparatively rare occasions when a general air movement northward across the Isthmus occurs, a tendency is noted for southwest winds in the Gulf of Panama to become southeast winds at Colon. Similar influences are apparent at no other time. This peculiarity is perhaps due to a general surface drainage northward across the Isthmus from the head of Panama Bay over the lowest point in the divide toward the Caribbean.

The Cape Mala instruments were located on top of the lighthouse, a skeleton steel tower, 100 feet high and about 140 feet above the level of the sea, also well above every neighboring object. The station is open to sea exposure from north through east to southwest. The land is low and comparatively level for several miles inland. At a distance of about 6 miles low hills attain an elevation of 300 feet, and about 20 miles west-northwest of the station near the center of the peninsula a maximum elevation of about 3,000 feet is attained over a small area. There are no valley formations that could affect local winds

At the naval air station at Coco Solo most pilot-balloon flights have been made for practical purposes only and to comparatively low levels. Prior to August, 1924, their standard flight was to 2,000 meters; after that date it was increased to 3,000 meters, cloud conditions permitting, with an occasional flight to higher levels. These records furnish averages that are probably a good index to the general air movements up to the three or four thousand meter level.

AIR AND WATER TEMPERATURES

The records at Colon and Cape Mala would seem to be nearly free from local influences, with the exception of the land and sea breeze. These winds at Colon would have a tendency to blow toward and from the hill area to the eastward of the station, while at Cape Mala the direction would be toward and from the hill area to west-northwest of the station. As these winds are due to temperature contrasts, between the land and water surfaces, and as the temperature of the Caribbean all of the year, and of the Pacific most of the year, does not vary much from the mean air temperature over the land, the land and sea breezes are comparatively light. In fact, they seldom appear as such, but are evident only as a diurnal variation in the general winds.

Average air temperatures at Colon and Cape Mala and average water temperatures of the Caribbean and of the Pacific are as follows. The water temperatures are from the averages of bihourly values of water thermographs in Colon and Balboa harbors, and immediately adjacent to water about 40 feet in depth.

AIR TEMPERATURES AT COLON—AVERAGE OF 19 YEARS' RECORD

Mean daily	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Maximum	84.0	84.0	84.7	85.3	85.8	85.2	84.8	84.8	85.7	85.4	83.9	84.2	84.8
Minimum	76.3	76.2	76.8	77.0	76.2	75.5	75.9	75.6	75.0	74.5	74.6	75.8	75.8
Range	7.7	7.8	7.9	8.3	9.6	9.7	8.9	9.2	10.7	10.9	9.3	8.4	9.0

AIR TEMPERATURES AT CAPE MALA—AVERAGE OF 33 MONTHS' RECORD

Maximum	84.9	84.5	85.9	85.8	86.3	84.9	84.2	84.2	83.7	83.3	84.5	85.0	84.8
Minimum	74.6	73.7	73.7	75.4	75.4	74.1	74.0	74.0	73.2	73.0	73.6	74.2	74.1
Range	10.3	10.8	12.2	10.4	10.9	10.8	10.2	10.2	10.5	10.3	10.9	10.9	10.7

WATER TEMPERATURES—COLON AND BALBOA—AVERAGE OF 19 YEARS' RECORD

Colon	80.3	80.2	80.8	82.1	82.7	83.4	83.0	82.9	83.3	83.0	81.9	81.2	82.1
Balboa	78.6	74.5	73.1	76.2	81.6	82.9	82.4	82.8	82.8	82.2	81.4	81.0	80.0

The range of air temperature would probably be several degrees greater at interior stations, although the high humidity and limited extent of land area prevents any great variation. The greatest departure in water temperature is in the Pacific in February and March, at the time of the greatest northward extension of the cold Peruvian current. The temperatures given are for Balboa, at the head of Panama Bay, and nearly 100 miles from Cape Mala. Ship reports frequently show temperatures 5° lower near the entrance of the bay. At Cape Mala in the month of March during the hottest part of the day temperature contrasts between land and water surfaces of 20° or more frequently occur. At Colon the maximum temperature differences would probably be less than half this amount.

LOCAL WIND RECORDS AS AN INDEX TO GENERAL AIR MOVEMENTS

The Colon record, complete for the 19-year period, 1908–1926, inclusive, under essentially similar conditions throughout, would seem to offer the best index to general wind movement over the Isthmus. For purposes of check and comparison, the record at Cape Mala, although covering only a short period, would, on account of its location and freedom from local influences, seem to offer the best material. The available record at Cape Mala, with simultaneous values of both wind direction and velocity, covers a period of slightly under three years, during 1919–1922. The record for 33 months has been summarized, 18 months complete and 15 months with hours missing. The missing record is so distributed as to have little effect on the monthly means.

The coordinates of the two stations are: Colon, 9° 21′ N., 79° 54′ W.; Cape Mala, 7° 28′ N., 80° 00′ W.; making Cape Mala 113 nautical miles almost due south of Colon. The stations are situated on opposite sides of the Isthmus,

the relative positions of land and water areas are nearly the reverse of each other, and the distance apart is sufficient to eliminate all common local influences.

For comparison with free air data, the following observations made at the naval air station at Coco Solo over a period extending from January, 1922, to March, 1927,

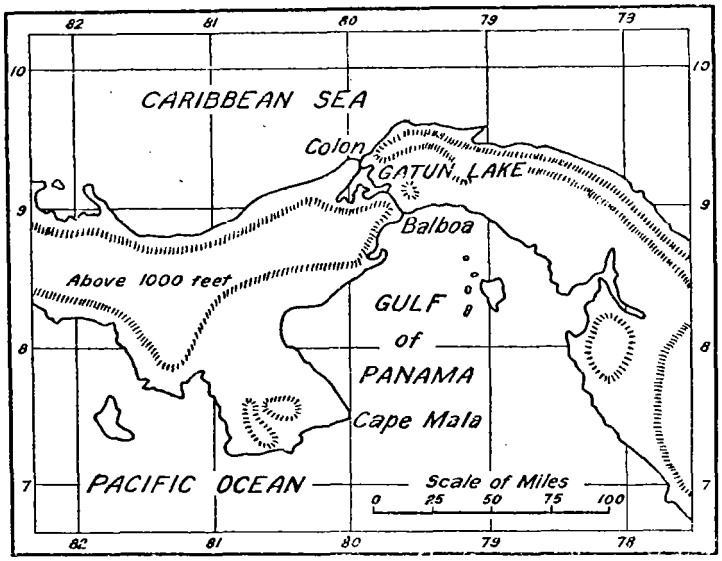

FIG. 1.—Isthmus of Panama

are available: Number of observations at 1,000-meter level, 1,109; at 2,000-meter level, 498; at 3,000-meter level, 217; and at 4,000-meter level, 60. These numbers include both morning and afternoon flights, and only selected levels are considered. The number of observations above the 1,000-meter level are too few for precise averages, but afford material for interesting comparisons with surface conditions.

An outline map of the Isthmus of Panama showing relative positions of land and water areas and of the meteorological stations mentioned is shown in Figure 1.

WIND DIRECTION

Annual variation at Colon and Cape Mala.—The annual march of wind frequencies at Colon and Cape Mala is shown in Figure 2. It will be seen that the winds during the trade-wind season are mostly from the north and northeast at Colon, while at Cape Mala they are from the northwest and north. Northerly winds of considerably decreased velocity make up a substantial proportion of the total during the rest of the year, but the prevailing directions are usually southerly or westerly, ranging from southeast to west at Colon and from southwest to northwest at Cape Mala. No general air movement from the east is in evidence at any time.

Diurnal variation at Colon and Cape Mala.—As mentioned previously, the land and sea breeze seems to be the only local influence at either station, and this usually appears only as a deflective force acting upon the current prevailing winds. Consideration of the diurnal variations peculiar to each station, due to this cause, is necessary in a comparison of wind directions. As will be seen from the map, the sea breeze at Colon would tend to blow toward the elevated area to the east of the station, while at Cape Mala it would tend to blow very nearly in the opposite direction, toward the west-northwest.

At Colon all winds tend to shift toward the west or northwest during the afternoon, under the influence of the sea breeze; under the influence of the land breeze, during the night and early morning, northerly component winds will tend to shift through north toward northeast and east, while southerly winds will back through southwest and south toward southeast.

At Cape Mala nearly the reverse is true, all winds tending to shift toward west and northwest during the night and early morning under the influence of the land breeze; northerly component winds shifting to north and southerly component winds backing to southwest and south during the afternoon under the influence of the sea breeze. The range of variation depends upon the force of the winds, the high winds holding steady with but little change.

It will be seen that the direction of the land-sea breeze line at both stations is very nearly ESE.–WNW., one station being the reverse of the other, and that the northerly and southerly component winds at each station, considered in their relation to this line, have a distinct diurnal variation of their own. The diurnal variation during the height of the trades, from January to March, is almost wholly of the northerly component type characteristic of each station, while the diurnal variation, late in the rainy season, during September and October, is equally characteristic of the southerly component types. The winds of the other months are a transition stage between these extremes, the two types being intermingled in varying proportions in the monthly averages.

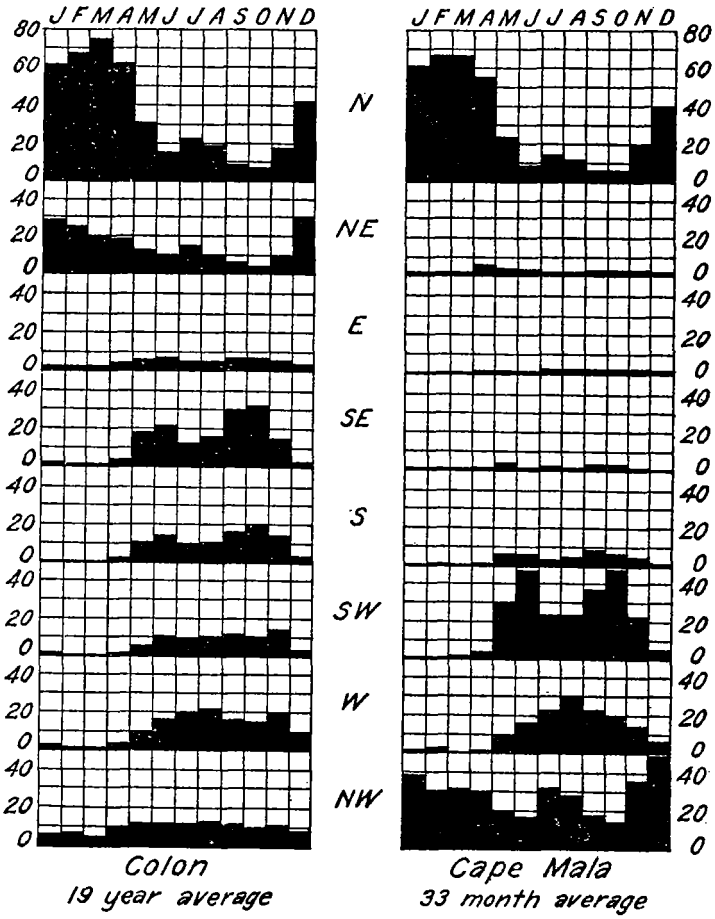

FIG. 2.—Annual march of wind frequency at Colon and Cape Mala, in percentages

Mean direction of the trades.—The diurnal variation typical of the trade winds is shown in Figure 3 (19-year averages for February at Colon and 3-year averages for January–February at Cape Mala).

At Colon the deflective effect of the land breeze appears in the averages as a marked increase in the frequency

of the northeast winds during the early forenoon. As the extreme shift to northwest under the influence of the sea breeze seldom occurs, it would appear that the mean direction of the trades at Colon is somewhat to the east of north.

At Cape Mala, from January to March, inclusive, the force of the land breeze is probably very light, if

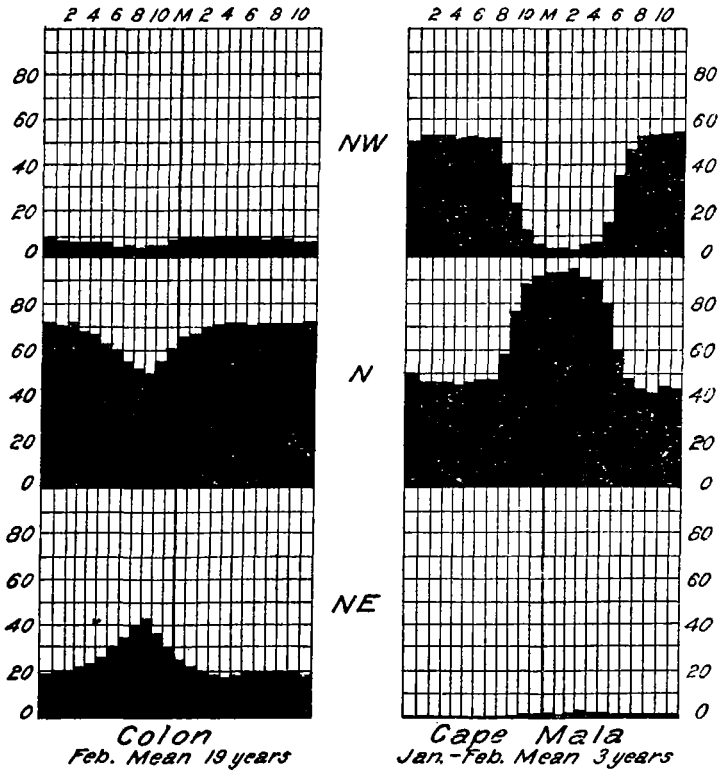

FIG. 3.—Diurnal march of wind frequency at Colon and Cape Mala, in percentages (trade-wind types)

not entirely nonexistent at times, due to the low ocean temperatures at that time of the year. Although the record is not long enough to warrant the same consideration as the Colon record, general tendencies are probably indicated. The mean direction of the trades at Cape Mala would appear to be very close to north-northwest, with the deflective force of the sea breeze causing a marked shift toward north during the hottest part of the day, backing toward northwest during the night and early morning. Inspection of the records show that the highest winds, during periods of intensified trades, tend to blow straight from the north at both stations.

Wind direction during the rainy season.—The diurnal variation typical of the other extreme, with southerly component winds at a maximum, is shown in Figure 4 (19-year average for September at Colon, and 3-year average for September–October at Cape Mala).

At Colon the extreme variation in southerly component winds is from the east or southeast during the night, through south and southwest to west or northwest during the afternoon, with southeast and west the most frequent. Every possible gradation occurs, but there are two main types—one in which westerly winds predominate, with a shift to southerly points for only a few hours in the early morning, and one in which southerly winds predominate, with a shift to westerly for only a few hours in the afternoon. The only southerly component winds that attain any great force or steadiness are from the southeast. High westerly winds may blow for a few hours at a time, but usually shift to other directions before the day is over. But at times of general air movement from the Pacific across the Isthmus toward the Caribbean the wind may blow steadily from the southeast for several days at a time.

At Cape Mala southerly component winds range from south and southwest during the day, toward west during the night, with southwest winds predominating. Winds from the northeast, east, and southeast are confined to local storms and periods of comparative calm. The only southerly component winds attaining great steadiness are those from the southwest.

A comparison of days with southerly winds at Colon and Cape Mala during the rainy seasons of 1919, 1920, and 1921 shows 20 days at Colon and 39 days at Cape Mala within the limits of the classification. The average wind movement at Colon for the 20 days was 83 per cent from the southeast, and at Cape Mala for the 39 days was 92 per cent from the southwest, showing the tendency mentioned before for southwest winds in the Gulf of Panama to become southeast winds at Colon.

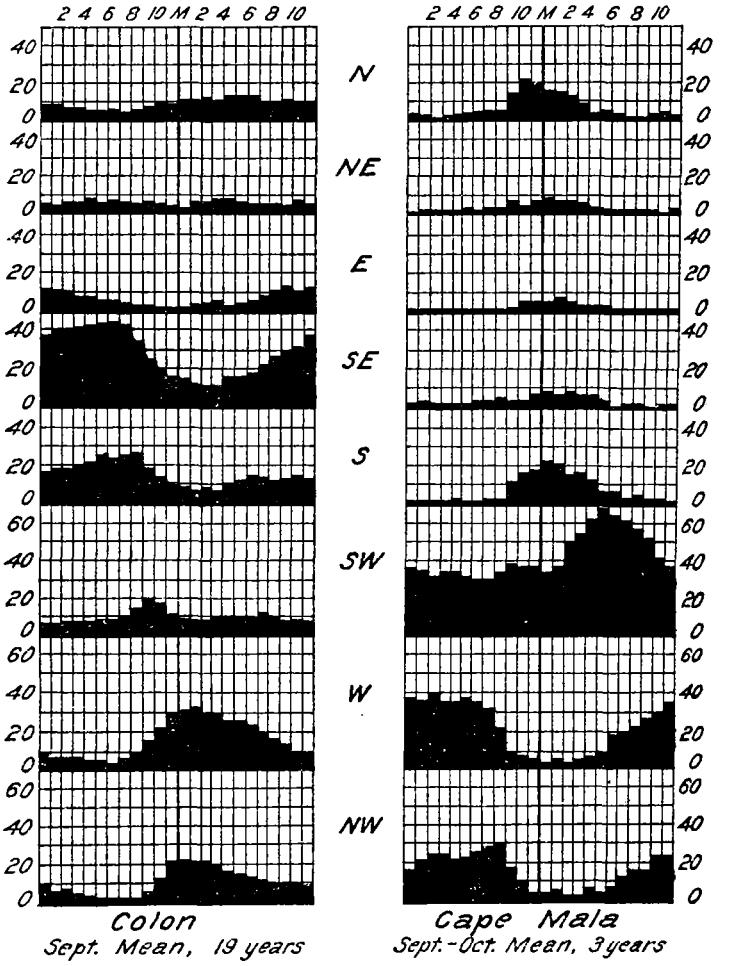

FIG. 4.—Diurnal march of wind frequency at Colon and Cape Mala, in percentages (rainy-season type)

While westerly winds at Colon are usually subject to the diurnal effect characteristic of southerly component winds, they may at Cape Mala vary either to the north or the south under the influence of the sea breeze. At Colon, in a rough classification, westerly winds can be segregated from northerly and southerly, but at Cape Mala this can not be done, as the westerly winds are too closely intermingled with the other two direction groups.

Near the beginning of the rainy season the trades begin to weaken, the range in diurnal variation increases, and southerly component winds appear, the two being intermingled in the averages. Early May and late November frequently represent about an equal distribution of the two types. During June, and again in September and October, northerly winds are very little in evidence, and southerly winds predominate. But near the middle of the rainy season, in July and August, there is almost always a period of marked recurrence of northerly winds, with southerly winds only occurring during

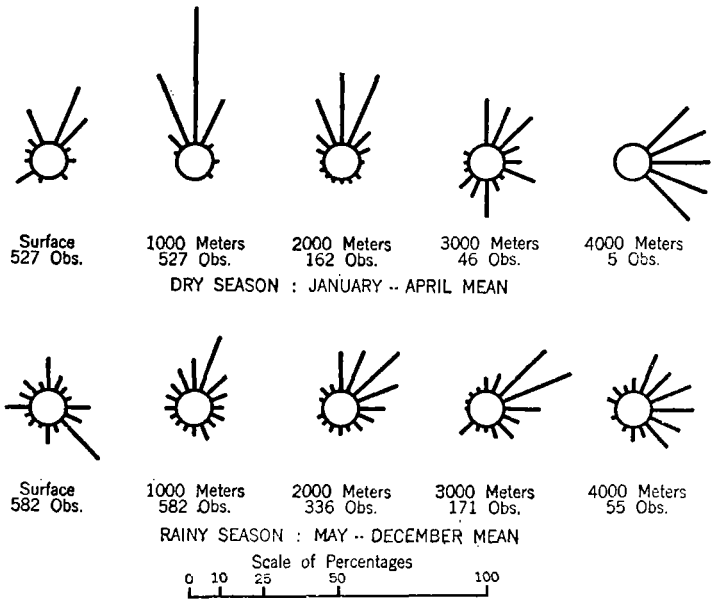

FIG. 5.—Wind frequency at selected levels for dry and rainy seasons, in percentages (Coco Solo)

local storms, or for a few hours as a part of the diurnal variation.

Free air wind directions.—Wind frequencies at selected levels in the free air are shown in Figure 5 (averages for the dry season, January to April, and for the rainy season, May to December, inclusive). All available pilot-balloon flights of 1,000 meters or more made at the naval air station, Coco Solo, up to the end of March, 1927, are included.

Wind percentages at the surface and 1,000-meter level are directly comparable. In the dry season averages, the surface winds are mostly from the north-northwest to northeast, with an average direction of N. 7° E. At the 1,000-meter level the range in variation is not so great and the average direction is N. 4° W. This would seem to indicate that the mean direction of the trades over Colon, unaffected by surface influences, is very nearly due north, with a small westerly departure from the surface mean. Beginning near the 2,000-meter level, the dry season winds become more and more variable, with a general shift toward the east.

In the rainy season averages the surface means show a marked preponderance of southeast, west, and north winds. At the 1,000-meter level this distribution disappears and the winds are well distributed among all the directions, with a marked concentration toward north-northeast. With increase in altitude, the winds continue variable, but with the average direction more and more easterly. At the 4,000-meter level it would seem that the difference between the seasons had practically disappeared. The winds are more or less variable in direction, but average very nearly due east throughout the year.

On days with intensified trades the wind direction holds steadily between north and north-northeast up to the 1,500-meter level. Observations at higher levels are not available. On days with constant southerly winds at the surface the wind direction varies from southeast at the surface through south to south-southwest at an elevation of 2,500 meters.[2]

WIND VELOCITIES

Annual variation at Colon and Cape Mala.—The annual march of monthly mean wind velocities for Colon and Cape Mala is shown in Figure 6. The Cape Mala winds follow a regular curve, with a maximum monthly mean of 21 miles per hour in February, a minimum of 8.2 in July, and an annual mean of 13.2 Velocities at Colon are generally lower, with a maximum of 15.8 in February a minimum of 6.9 in June and September, and an annual mean of 10.5. The greatest difference occurs during the trade-wind season. A departure from the regular curve occurs in the Colon record during July and August. This does not signify a general increase in velocity, but is a local effect, due to a change in the prevailing direction from off-shore to on-shore winds, as previously noted.

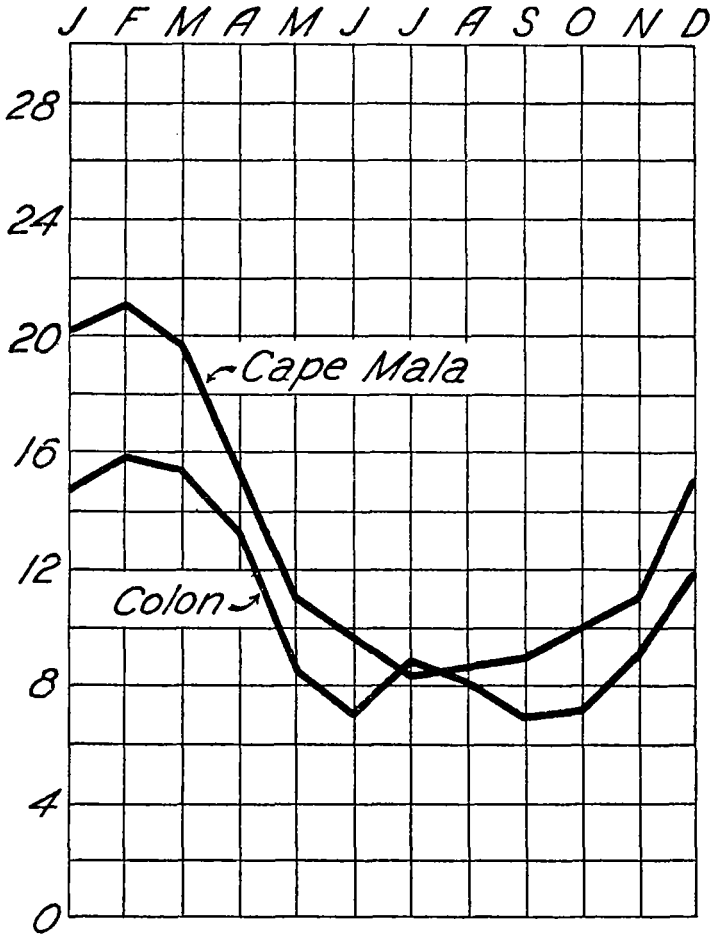

FIG. 6.—Annual march of wind velocity at Colon and Cape Mala, in miles per hour

Diurnal variation at Colon and Cape Mala.—The diurnal march of wind velocities for March and September is shown in Figure 7.

Free air wind velocities.—Comparative values of wind velocities at selected levels for the dry and rainy seasons are shown in Figure 8. The averages are based on the

[2] This is one more example illustrating the apparent universality of the turning of the wind with altitude in the Northern Hemisphere as found in kite and pilot-balloon flights in the United States and elsewhere.—ED.

same number of observations as in Figure 5. The January–April means show an average of 15.4 miles per hour at the surface, increasing to 18.1 at the 1,000-meter level, and falling off to 12.8 and 11.2, respectively, at the 2,000 and 3,000 meter levels, considerably lower than the surface velocity. Inspection of the records shows that maximum velocities in the altitudes under consideration are attained at about the 750-meter level.

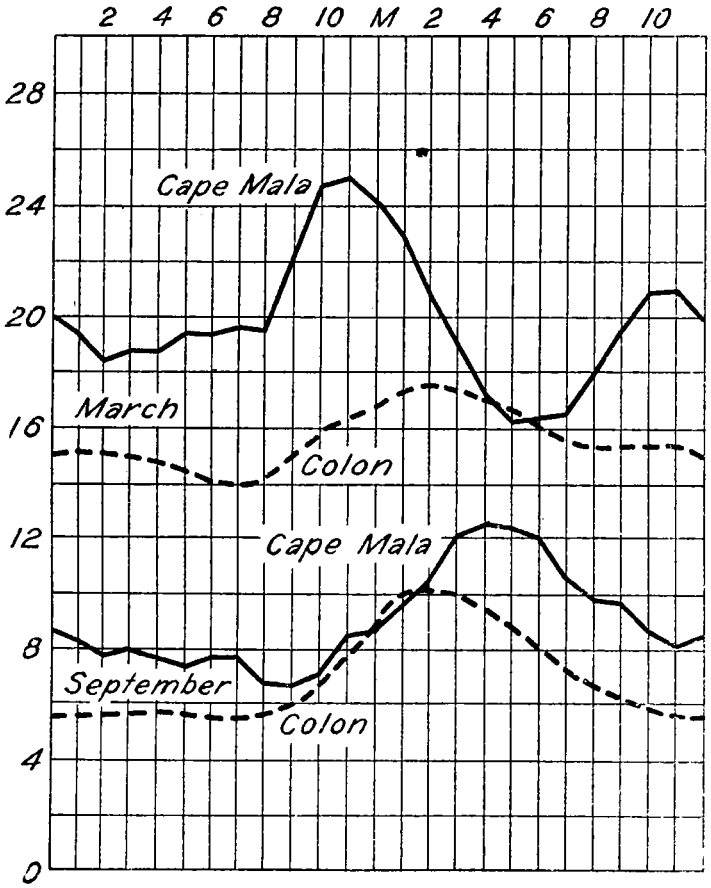

FIG. 7.—Diurnal march of wind velocity at Colon and Cape Mala for representative months, in miles per hour

The May–December means also show a slight falling off above the 1,000-meter level. At an elevation of three or four thousand meters it would seem that the velocities are much the same throughout the year and only slightly higher than the mean annual surface velocity. Occasional flights to higher altitudes show little or no increase up to six or seven thousand meters.

Distribution of mean daily velocities.—Wind velocities at Colon, based on the 19-year record, 1908–1926, inclusive, are light and show no great variation. In a tabulation of frequency distribution of daily mean velocities, it is shown that 54 per cent of the days during this period had mean velocities under 10 miles per hour, and only 2 per cent mean velocities greater than 20 miles per hour. Only five days during the entire period have had mean velocities in excess of 25 miles per hour, and only one day in excess of 30 miles per hour. During February, the month of greatest velocity, 83 per cent of the days have velocities between 10 and 20 miles per hour. Eight per cent have velocities under 10, and 9 per cent velocities over 20 miles per hour. During September, the month of least velocity, 76 per cent of the days have velocities between 5 and 10 miles per hour, 14 per cent under 5 miles per hour, and 10 per cent over 10 miles per hour. Only one day in the entire period had a mean velocity greater than 15 miles per hour.

Maximum velocities at Colon are also low and show little variation. A comparison of the average hourly velocities for the various months and the average of the daily maximum velocities, together with the absolute maximum, follows:

	January	February	March	April	May	June	July
Mean	14.6	15.8	15.5	13.3	8.4	6.9	8.4
Maximum	22.7	23.6	22.4	20.8	17.1	16.8	17.9
Difference	8.1	7.8	6.9	7.5	8.7	9.9	9.5
Absolute	36 N.	39 N.	36 NE.	46 N.	36 N.	33 W.	40 S.

	August	September	October	November	December	Annual
Mean	8.1	6.9	7.2	9.0	11.9	10.5
Maximum	17.9	17.0	17.4	20.1	21.4	19.6
Difference	9.8	10.1	10.2	11.1	9.5	9.1
Absolute	32 S.	37 W	40 NW.	42 NW.	38 N.	46 N.

November is shown as the month of the greatest "squalliness," as would be expected along the front of the advancing trades. March, at the height of the trade-wind season, is the month of the steadiest winds. Only five days in the entire 19-year period have had maximum velocities greater than 40 miles per hour.

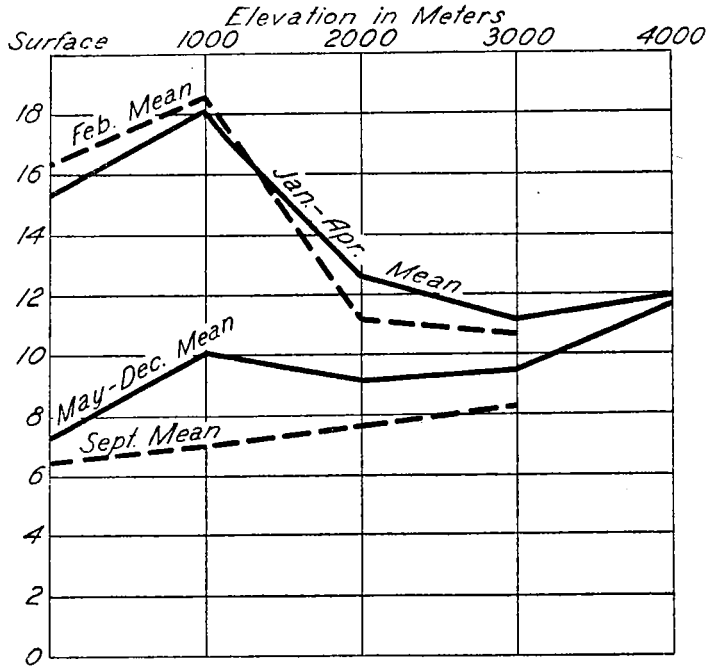

FIG. 8.—Comparative values of wind velocities at selected levels for dry and rainy seasons, Coco Solo, miles per hour

At Cape Mala both daily mean and daily maximum velocities are considerably higher than at Colon. In the three-year period under consideration there were 62 days with maximum velocities above 40 miles per hour. The absolute maximum at Cape Mala is 58 miles per hour from the northeast during a local storm. Dry-season velocities up to 56 miles per hour from the north have been recorded, marking the culmination of intensified trades.

GENERAL WINDS AND THE DISTRIBUTION OF STORMS

Associated wind groups.—As suggested before, the winds at Colon may be divided into three separate direction groups with distinct causes and associations. The significant facts seem to be brought out better by a grouping of related wind directions than by resultant values. This is possible in the Colon record, as the three groups, although intermingled much of the time, are still sufficiently distinct to be segregated.

Northerly winds, including those recorded from the north and northeast, constitute a measure of all positive wind movement southward across the Isthmus. The trades are covered by this class, and also the comparatively light and shallow northerly winds of the middle rainy season, which, while perhaps not indicating positive movement across the Isthmus, at least indicate complete absence of any positive movement from the south.

Southerly component winds may be divided into two distinct classes, southerly and westerly. Although combined in the typical diurnal variation of the rainy season, a marked preponderance of either is due to entirely different causes.

In the classification of southerly has been included all winds recorded from the east, southeast, south, and southwest. Those from the southeast predominate locally, with the other directions largely phases in the diurnal variation. Any of these winds may be local, but a marked increase in their relative proportion indicates a positive movement northward across the Isthmus.

Westerly winds, including those recorded from the west and northwest, may be considered as neutral and a marked increase in the relative proportions of these winds as indicating the absence of any positive northerly or southerly movement. They are associated with light winds from all directions, but especially with the light northerly winds of the middle rainy season.

At Cape Mala it is impossible to segregate the westerly winds from the northerly and southerly on account of the lesser range in diurnal variation, but they are probably divided about equally between the other two classes, so as to not affect materially their relative proportions. Northerly winds at Cape Mala include those recorded from northwest and north, covering the trades and all similar winds. Southerly winds include those recorded from the south, southwest, and west, constituting a measure of all positive southerly movement. Southwest winds predominate. Any general air movement from easterly directions is negligible in the surface winds of both stations.

Seasonal variation.—The seasonal variation in wind movement classified in the above manner is shown in Figure 9.

In the Colon record the westerly or neutral winds increase with great regularity from a minimum of less than 10 per cent in January, February, and March to a maximum of 40 per cent in August. If it were possible to segregate the westerly winds, probably about the same proportion would be shown in the Cape Mala record. A marked increase in movement from the south is indicated in the records of both stations during June and again in September and October, reaching a maximum in the latter month. The southerly winds are interspersed by a marked increase in northerly wind movement during July and August. These winds, coupled with the maximum of westerly winds, both probably due to mild monsoon influences toward the South American Continent, indicate a decided absence of any positive general wind movement during that season.

General winds.—The only winds of the Isthmus of Panama that may be considered general in character and a part of an extensive air movement over wide areas are the northeast trades and the short intermittent periods of southerly winds most frequent in October. According to available free-air data, the influence of the trades extends upward to at least 3,000 meters, although a marked decrease in velocity and a shift toward easterly occurs shortly above the 1,000-meter level. On days with constant southerly winds at the surface available free-air data indicate that they persist to a height about equal to that attained by the northeast trades, although, with lower velocity throughout, a shift toward southwest occurs with increase in elevation. A general air movement across the Isthmus is shown, extending to a height of three or four thousand meters and perhaps higher.

Westerly winds seem to be shallow as they become variable at low levels, but at times probably cover quite

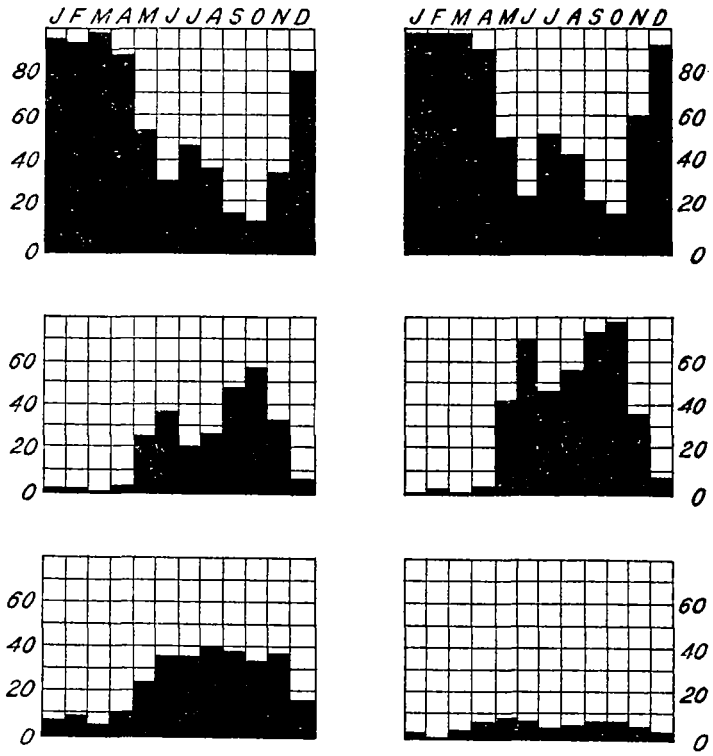

FIG. 9.—Seasonal variation in wind movement of groups of related winds at Colon and Cape Mala, in percentages

an extensive area. They are spoken of by the old Spanish navigators under the term "vendavales." These winds were encountered in the southwestern Caribbean from Cape La Vela on the north coast of Colombia westward to the Nicaraguan coast, and are described as especially prevalent in the middle rainy season. They appear as a substantial element in the wind movement at Colon and also at Cape Mala. It would seem probable that they are associated with the trades still persisting over the eastern Caribbean.

DISTRIBUTION OF STORMS

The only storms in the Central American region covering any great area are northers, tropical cyclones, and the general and long-continued rains causing our big floods. Their distribution, by months, and a comparison with the average percentage of wind movement at Colon classified in groups of related winds follows. All values are for the 19-year period, 1908–1926, inclusive.

	January	February	March	April	May	June	July	August	September	October	November	December	Totals and means
STORMS	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Northers	0	1	0	1	0	0	0	0	0	0	2	2	6
Cyclones	0	0	0	0	0	4	0	1	4	14	7	0	30
Floods	1	0	0	0	1	1	0	0	0	1	3	3	10
WIND	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Northerly	93	92	96	86	53	29	46	35	16	10	33	79	64
Southerly	1	1	0	3	24	37	20	25	47	57	31	5	17
Westerly	6	7	4	11	23	34	34	40	37	33	36	16	19

The list of northers includes only those storms occurring locally on the north coast of Panama, and that unquestionably can be classified as such. In the MONTHLY WEATHER REVIEW for November, 1917, a list of northers is given from French records occurring prior to American occupation of the Canal Zone. Nine of these storms specifically classified as such are distributed as follows: October, 1; November, 2; December, 3; January, 2; and February, 1. The distribution is much the same as shown in the above tabulation.

Tropical cyclones in the above tabulation include all of those storms positively indentified as such and first reported anywhere in the western Caribbean between latitude 10° to 20° N. and longitude 75° to 90° W.

The classification floods includes periods of heavy rainfall extending over several days or a week, during which time the maximum momentary discharge of the Chagres River at Alhajuela has exceeded 50,000 cubic feet per second. This would include major floods only occurring at times of continued and general rains, unquestionably due to influences other than local. In Willson's Climatology and Hydrology of the Panama Canal six great floods on the Chagres River are mentioned prior to 1908, all occurring between November 20 and December 25, and three of them, those of 1879, 1885, and 1906, associated with destructive northers. In the tabulation above the storms occurring from late October to late December greatly exceed in intensity and duration the storms of any other season.

The tabulation shows a major concentration of general storms of all classes near the end of the rainy season and along the front of the advancing northeast trades and a lesser concentration of general rains and cyclones only near the beginning. The positive relation between the occurrence of cyclones and the percentage of southerly winds at Colon is obvious. During October to December, inclusive, the maximum of the hurricane season is closely followed on the Isthmus of Panama by the period of general rains, which in turn merges into the period of northers and lesser gales, which may continue until the definite establishment of the trades late in December.

This does not take into consideration intensified trades,[3] which are really not storms at all, but might be considered as the maxima in a normal variation of the trades. They develop slowly and very seldom cause any damage, but sometimes constitute a considerable inconvenience, if not danger to small vessels along windward coasts.

Diurnal variation of rainfall as an index to the character of storms.—As another indication of the varying character of our storms, the diurnal march of the amount of rainfall at Colon for representative months is given herewith. The values are comparative percentages and are the average of 20 years' record.

Month	Hours, midnight to midnight								Average monthly rainfall
	12-3	3-6	6-9	9-12	12-3	3-6	6-9	9-12	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	
March	80	173	129	62	71	155	63	61	1.34
May	115	108	111	61	122	143	78	63	12.84
August	93	121	123	69	149	101	70	69	14.56
November	120	121	121	86	91	96	86	81	21.59

The early morning maximum especially noticeable in August is a more or less local effect, due to nighttime thunderstorms off the Caribbean. There is also a local effect in the afternoon maximum, depending upon the distance of hill areas acting as centers of thunderstorm formation.

The general character of the November rains is clearly indicated. There is no sharp morning maximum, but rains are considerably above the average from midnight to 9 a. m., and the afternoon maximum, so marked a feature of the other months, has almost disappeared. The distribution for May and August is characteristic of rains of local thermal origin. The rainfall for March is confined to the light squalls of the trade-wind season. The maxima seem closely associated with the daily minimum temperature and the daily maximum velocity of the wind.

NORTHERS AND OTHER HIGH WINDS

Historical northers.—Unlike the intensified trades, all available evidence indicates that destructive northers are not associated with well-established trades. They are invariably preceded for several days by light southerly or variable winds. Their development is rapid, which perhaps accounts for much of the damage done. In the old days in Colon Harbor, before the construction of the breakwaters, steam vessels were usually able to put to sea after the storm started, but sailing ships were frequently caught and wrecked. Most of the shore damage was done by sailing vessels being wrecked and driven by the waves into the wharves along the water front, destroying them and ruining the cargo stored thereon.

The historical northers were probably remembered more for the damage they caused than for their meteorological associations. Ten of these storms occurring between 1857 and 1906 are specifically listed in the MONTHLY WEATHER REVIEW for November, 1917, referred to above.

One of these storms, that of October, 1865, would seem to be open to question. In the French classification the statement is made that the wind was from the southwest and that the storm lasted only six hours with $300,000 damage. In the issue of October, 21 1865, of the Panama City Star and Herald we find this description. The storm is spoken of as a temporal or tempest and is described as the most severe storm in many years. "It commenced on the night of the 17th, continued during the 18th and 19th, and partially subsided on the 20th. The wind blew a perfect gale and the rain, with short intermissions, fell in torrents." It specifically states that the storm was also felt on the Atlantic side of the Isthmus, but that no material damage was done in Colon. The sea in Panama Bay was described as very rough, local vessels being unable to reach the small islands close offshore for several days, and that a steam vessel with great

[3] Whenever and wherever the southeast quadrant of a well-organized anticyclone meets and merges with the northeast trades the velocity of the latter must be temporarily increased. The suggestion is made, however, that both intensified trades and northers belong to the same generic class although possessing distinctive features that warrant separate classification.—ED.

difficulty escaped going on the rocks at Taboga Island. Evidently the wind was southerly. This storm could not be rightfully classified as a norther, but might have been associated with hurricane formation.

In describing damage due to the above storm it was probably confused in the tabulation with the storm of January 18–19, 1873. The Star and Herald of January 21, 1873, says: "Fearful norther began 11 p. m. on the 18th. Three-masted schooner *Royal Arch* wrecked and carried through Pacific Mail wharf. Loss to cargo and damage to wharf, $300,000." In the issue of January 25 it states that many more ships were lost, three men drowned, and total damage on the Colon water front estimated at one-half million.

The issues of the Star and Herald for December 4 to 9, 1885, has the following to say about the norther of that year: "Terrible gale from the northeast began at noon the 2d. Before the storm the wind changed from southwest through west to north. Wharf No. 4 almost demolished. Fourteen sailing vessels lost in Colon Harbor." The great loss of life on the wrecked vessels is deplored, the waves being so high it was impossible to rescue the crews.

Classification of high winds at Colon, 1908–1926.—For the last 19 years, 1908–1926, inclusive, detailed data concerning wind direction and velocity during and preceding these storms are available. If the statements of old-timers can be credited, no storms during this period have equalled the intensity of the storms of past years.

While northers have characteristic peculiarities of both wind and other elements, any classification from the meteorological standpoint would have to be based on wind velocity. Any arbitrary standard adopted would be based on a proper relation with average wind conditions and should be sufficiently high to include only periods worthy of note. Such classification, however, would necessarily include many periods of high winds lacking in the other characteristics of northers. The highest mean for any month in the 19-year period is 18.3 miles per hour in February, 1923, during which month no norther occurred. This would indicate that velocities slightly above 20 miles per hour for several hours during the afternoon would not be unusual. Adopting an arbitrary minimum standard of 25 miles per hour for three consecutive hours, all periods exceeding this limit either in velocity or duration have been considered as worthy of inspection.

In the 19-year record there are only 80 such periods, or an average of 4 per year. Only 7 exceed 10 hours in length, with a maximum duration of 30 hours during the norther of April 3–5, 1915. Only two periods have an average velocity above 30 miles per hour, both occurring during northers. If we combine periods of high winds occurring on consecutive days and consider them for what they really are, separate maxima of the same meteorological formation, the number is reduced to 63. Classified according to their characteristics as intensified trades, northers, or gales, including high winds that can not be included under the other two heads, the distribution is as follows:

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Intensified trades	0	0	4	20	11	12	4	51
Northers	0	2	2	0	1	0	1	6
Gales	2	2	2	0	0	0	0	6
Total	2	4	8	20	12	12	5	63

Intensified trades.—The intensified trades are confined to the months December to April, inclusive, as would be expected, with the maximum frequency in January. February and March winds, while of higher average velocity, seem to be steadier. General conditions during intensified trades differ in no respect from the hours and days immediately preceding and following, except in a slightly higher wind velocity and a heavier sea.

During the three seasons, 1919–20, 1920–21, and 1921–22, simultaneous wind records are available at both Colon and Cape Mala. In tabulating the Cape Mala record a standard of 35 miles per hour for three hours was adopted as being appropriate to the data and closely comparable with the tabulation of the Colon data. During the three years there are 16 days at Colon and 32 days at Cape Mala with periods of high winds above the limits of the classification. No northers occurred during these years. A summary of the comparison follows. The velocities compared are mean velocities for 24-hour periods, midnight to midnight, for the days on which periods of high winds occurred.

	Days with high winds at—					
	Colon only		Both Colon and Cape Mala		Cape Mala only	
	Colon	Cape Mala	Colon	Cape Mala	Colon	Cape Mala
Number of days	8.0	----------	8.0	8.0	----------	24.0
Average velocity (miles per hour)	21.0	21.2	21.4	34.9	18.1	30.9
Departure preceding day	1.5	−0.3	2.1	9.1	−0.4	7.2
Average 8 a. m. barometer	.894	.841	.922	.849	.926	.846

The average velocity of the 16 days with intensified trades at Colon exceeds the average velocity of the days immediately preceding by only 1.8 miles per hour. This well illustrates the character of these winds as the maximum of a gradual development.

The average departure at Cape Mala for the 32 days is 7.7 miles per hour, showing considerably greater variability. The barometer at Cape Mala shows little variation and remains very close to the seasonal average, but the Colon barometer displays noticeable peculiarities.

It will be seen in the above tabulation that intensified trades at Colon alone are associated with a barometer very close to the seasonal average. The increased velocity would seem to be due to a momentum initiated by pressure gradients farther to the north. Intensified trades at Cape Mala, whether occurring at that station only or at both stations simultaneously, are associated with a noticeably increased barometer at Colon, indicating a southward extension of the high-pressure belt.

If so small a number of observations can be considered significant, the relation of increased velocity to pressure distribution would seem to suggest the existence of local areas of intensification along the steeper portions of the pressure slope toward the equatorial trough. Of the 40 days considered intensification occurred at both stations simultaneously on only 8 days, and no relation between the periods at the two stations seems to exist; no progressive movement or extension of the intensification areas either north or south is indicated. The evidence would seem to support the view that a large percentage of intensified trades are a more or less local phenomenon.

Gales.—Of the six periods of high winds mentioned above under the classification "Gales" two each occurred during the months October, November, and December.

One of these periods, that of October 18, 1908, with the wind from the southeast and a maximum velocity of 30 miles per hour was associated with hurricane formation.

Three of these periods occurring on November 16, 1916, November 4, 1917, and October 22, 1923, were westerly gales preceded by light southerly winds. They resembled northers in everything except the wind direction and the heavy sea. The first of these closely followed the formation of a tropical cyclone in latitude 12° N. and longitude 80° W. on November 11, 1916. It was accompanied by moderately heavy rains. The second was a very similar formation. The third, on October 22, 1923, was a culmination of a two-day period of west and northwest gales on October 22 and 23, closely following a four-day period of strong southerly winds on October 16 to 19. It was associated with the heaviest rainfall of record on the Canal Zone.

The other two periods occurred on December 28, 1921, and January 1, 1922. They were intensified trades in their association except that they were accompanied by heavy rain squalls.

Northers.—Of the six northers occurring during the 19-year period, two each occurred in the months of November and December and one each in February and April. A tabulation of the mean daily values of wind velocity and direction, barometer, and rainfall at Colon, preceding and following these storms is given herewith. All values are for a 24-hour period, midnight to midnight. The mean barometer is the mean of the bihourly values of the even-numbered hours.

Date of norther	Daily means	Number of days before and after appearance						
		3	2	1	0	1	2	3
Nov. 17, 1912	Velocity	9.4	6.7	4.3	16.1	20.8	19.9	19.2
	Direction	SE.	SE.	Variable.	WNW.	NW.	NW.	WNW.
	Barometer	.80	.86	.92	.90	.88	.86	.85
	Rain	.04	.12	.01	.02	.31	.12	.48
Nov. 24–25, 1917.	Velocity	7.2	11.2	18.1	27.3	22.7	11.9	12.3
	Direction	SW.	WSW.	NW.	NW.	NW.	NW.	NE.
	Barometer	.90	.88	.89	.94	.91	.89	.87
	Rain	1.02	.79	1.09	.26	1.27	1.08	.63
Dec. 3, 1910	Velocity	9.5	12.1	11.1	20.7	7.3	10.2	6.4
	Direction	S, NW.	WNW.	Variable.	N.	NE.	SW.	Variabl
	Barometer	.81	.84	.84	.86	.84	.79	.84
	Rain	3.65	2.14	.24	.91	2.51	.01	.05
Dec. 10, 1914	Velocity	8.8	5.8	10.0	20.8	16.7	10.3	8.3
	Direction	WSW.	Variable.	Variable.	NE.	NE.	NE.	SW.
	Barometer	.80	.78	.79	.78	.76	.78	.79
	Rain	0	0	0	.02	.02	2.22	1.09
Feb. 9, 1915	Velocity	11.0	13.6	16.0	18.6	15.7	21.3	21.0
	Direction	Variable.	Variable.	NNW.	NW.	N.	N.	N.
	Barometer	.88	.86	.88	.86	.86	.90	.88
	Rain	.31	.92	.01	1.46	7.12	1.69	.02
Apr. 3–5, 1915	Velocity	9.0	6.7	8.4	12.5	32.0	23.4	17.5
	Direction	N.	Variable.	SE, W.	Variable	N.	N.	N.
	Barometer	.82	.84	.85	.90	.95	.90	.88
	Rain	0	0	0	4.98	.52	.91	0

In the northers of 1912 and 1914 winds above 25 miles per hour obtained for only three hours. The duration was not long enough to develop any very heavy sea.

The norther of 1910 lasted for 10 hours. Light southerly winds on the forenoon of December 2 shifted to north during the afternoon and evening and increased in velocity. The period of high winds lasted from midnight to 10 a. m. the 3d. The sea was very rough, all large vessels left their berths at the Colon docks, and local water transportation and ship sailings were interrupted.

In the norther of November 24–25, 1917, velocities above 25 miles per hour obtained for 29 hours, from 3 a. m. the 24th to 8 a. m. the 25th, with a maximum velocity of 42 miles from the northwest. This is the second highest velocity in the 19-year record at Colon. The sea was very rough, but no material damage was done in Colon Harbor.

The dry season of 1915 was abnormal throughout.[4] The trades were never firmly established and the winds were characteristic of early December. The two northers of that year were unusual both as to time of occurrence and as to characteristics. Only once before since 1857 is any mention made of a norther occurring after the 1st of February.

The first one started on February 9, the wind increasing to above 25 miles per hour for four hours from 4 to 8 p. m. The early morning of the 10th the wind fell off and shifted to east and southeast, accompanied by very heavy rain. Seven and twelve one-hundredths inches fell in Colon on that day. By the night of the 10th the wind had shifted back to north with increasing velocity, attaining velocities above 25 miles per hour for five hours on the 11th from 5 to 10 p. m.

The second norther of 1915 began on April 3. Winds above 25 miles per hour lasted for 30 hours from 10 p. m. the 3d to 9 a. m. the 5th, with an average of 31 miles. The highest velocity was attained from 1 to 4 a. m. the 4th, with an average of 38 miles per hour and a maximum of 46 miles. This storm constitutes the record at Colon for both the daily mean and the maximum velocities. The high winds were preceded by light southerly winds and a thunderstorm. For the hour 3 to 4 p. m. of the 3d, only six hours before the norther had attained high velocities, the wind averaged only 3 miles from the south.

The two northers of 1915 were the most violent of the 19-year period and were the only ones causing any great damage in Colon Harbor. According to annual report of the Governor of the Panama Canal, the damage to the east breakwater, under construction, in these two storms was estimated at $370,000, and to the west breakwater, completed, at $100,000.

Northers would seem to be more closely related to the westerly gales mentioned above than to any other local meteorological formation. They are entirely distinct from intensified trades. The highest wind velocities at Colon, both momentary and average, have occurred in these storms, and they are the only storms that have caused any great damage. We have positive evidence that one of the northers under consideration, that of February, 1915, was a local storm, not being noticeable over 50 or 100 miles offshore. Reports from captains of incoming vessels during this period were to the effect that no rough weather had been experienced in the Caribbean. The steamship *Alliance* docking at 4 p. m. February 10, did not encounter rough seas until within 50 miles of Colon at noon of the same day. This suggests that all of them might be more or less local.[5] Their rapid development and quick subsidence and the wind shifts always associated with them would also suggest this. Their location on the immediate front of the northeast trades is evident. While their cause is probably an unusual flow of air from the north, the manifestations of strong winds, squalls, and rough seas which we designate by the term "norther" may be local phenomena.

[4] The year 1915 was abnormal over a large part of the Northern Hemisphere; the summer in the United States was unusually cool.

The northers of Feb. 9 and Apr. 3 at Colon doubtless were occasioned by great anticyclones on the several dates which stretched from the Great Lakes southward to an indeterminate distance over the Gulf of Mexico.—ED.

[5] Since the high pressure that induces the northerly winds advances from west to east, it may well have been that the *Alliance* met the advancing wave of high pressure but 50 miles distant from Panama. The author in a letter to the editor makes it clear that he considers the pressure distribution to the northward as the prime factor in norther causation; nevertheless, the local pressure distribution is also a contributing cause, and it was in this sense that the suggestion was made that northers might be more or less due to local phenomena.—ED.

SOUTHERLY WINDS AT THE ISTHMUS OF PANAMA AND TROPICAL CYCLONES

Periods of constant southerly winds, 1908–1926.—Southerly winds make up a substantial proportion of the total wind movement at Colon during all of the rainy-season months, but they usually appear only as the land breeze component in the daily variation. When they attain sufficient strength and steadiness to overcome the influence of the sea breeze and blow continually without shift for 24 hours or longer they seem worthy of note.

A tabulation of all days at Colon during the 19-year period, 1908–1926, inclusive, in which the wind blew continually from southerly directions (E., SE., S., and SW.), with a mean velocity of 7 miles per hour or more, may be summarized as follows:

	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Total number of days	10	18	1	8	35	60	27	0	159
Number of periods of consecutive days	8	14	1	7	21	29	17	0	97
Number of periods associated with hurricane formation	0	4	0	1	3	10	5	0	23

These figures show an average of only about 8 days a year on which the wind blows continually from southerly directions. The periods range in length from 1 to 6 days. There were 12 periods of 3 days or over. Ten of these were associated with cyclone formation in the western Caribbean. The two exceptions are September 10–12, 1924, and October 16–19, 1923.

On September 13, 1924, a disturbance appeared in the southeastern Gulf of Mexico, developing gale force on the Florida coast. About the right time interval existed for a mild cyclonic disturbance to drift from the southwestern Caribbean, on the 10th or 11th, across Yucatan, and its true nature be identified in the southeastern Gulf on the 13th.

Closely associated with the second instance was the development of a mild disturbance north of the east end of Cuba on October 22, 1923. About the right time interval existed here also. Apparently conditions were not favorable for the development of hurricane force in low latitudes. This suggests the development of other storms farther to the south than first reported and their true character established.

A study of the above tabulation would indicate that if the wind at Colon holds steadily to southerly directions for one day there is one chance in four that a tropical disturbance develops in the western Caribbean; if southerly winds persist for two days, the chances are two in five; and for three days or longer, it is almost conclusive evidence that at least a mild cyclonic circulation has developed.

In tabulating the Cape Mala data a standard of 13 miles per hour without shift from southerly directions (S., SW., and W.) was adopted as being appropriate to the data and roughly comparable with the Colon tabulation. For the three-year period, 1919, 1920, and 1921, for which comparable data are available, there were 20 days at Colon and 39 days at Cape Mala within the limits of the respective classifications. On 23 days southerly winds appeared at Cape Mala only; on 16 days they also extended north as far as Colon. The remaining four days at Colon were associated with constant southerly winds at Cape Mala, but with a less velocity than 13 miles per hour.

From the above it would appear that southerly winds are noticeable at Cape Mala first, that about half the time they also extend northward to Colon, and that their constancy and velocity is considerably greater at the former station.

During the years 1922–1926, inclusive, free-air data at the naval air station at Coco Solo are available on 26 days with constant southerly winds at Colon. In all of these observations, with one exception, southerly winds persisted to the highest level attained, 3,500 meters. The average direction, however, varied from southeast at the surface to south-southwest at the 2,500-meter level. The maximum velocity was attained between the 500 and the 750 meter levels, decreasing below surface velocity near the 2,000-meter level.

From the above it would appear that these periods of southerly winds represent a northward flow of air over a large area, deriving their initial momentum from pressure conditions in the South Pacific; that they are not surface winds, but extend upward to at least 3,500 meters; that their direction at upper levels is close to south-southwest or southwest, near the surface direction at Cape Mala; and that the Isthmus of Panama is near their northern limit. On these occasions when they extend across the Isthmus to the southwestern Caribbean and persist for a few days they seem to be intimately associated with the development of tropical cyclones in those waters.

TROPICAL CYCLONES, 1908–1926

Of the 30 tropical cyclones forming in the western Caribbean during the 19-year period, 1908–1926, inclusive, 14 were identified as such south of latitude 15°, or within 300 miles of Colon. The average wind and barometer conditions at Colon during the formation and development of these 14 storms is shown in Figure 10. As will be seen, an increase in velocity and southerly winds and a decrease in barometer is noticeable from the third day before the storm is first reported. Northerly winds are negligible throughout the 10-day period considered and southerly winds are well above the average even six days before the storm. The highest velocity and the lowest barometer occur on the day of reported formation, but the maximum of southerly winds does not occur until the day following.

No marked change occurs in the average wind velocity or in the barometer for the 16 storms first reported north of latitude 15°, but a marked preponderance of southerly winds obtains throughout the 10-day period, with a slight maximum the second day before the storm is first reported.

The arbitrary classification used above does not bring out the significant facts in all cases. When storms form east of the eightieth meridian, southerly winds at Colon may shift to west, returning to southerly as the storm advances northward. The storm of November 22, 1909, was immediately preceded by a marked preponderance of westerly winds of high velocity, shifting to southward the day following its formation. This storm is reported as forming in latitude 11° N. and longitude 78° W., very nearly northeast of Colon. Similar conditions accompanied the formation of several other November storms.

Of the 30 storms under consideration, 24 were associated with days of constant southerly winds at Colon. Of the remaining 6, 5 were first reported north of latitude 17° and west of longitude 82°, or more than 500 miles from Colon and outside the southwestern Caribbean.

The remaining storm is the one mentioned above, of November 22, 1909, when the usual southerly winds were replaced by westerly.

During the three-year period for which records are available at Cape Mala three tropical cyclones occurred. The first one was reported September 19, 1920, in 16° N. and 85° W. Constant southerly winds blew at Cape Mala for the four-day period, September 17–20, inclusive, and at Colon for the two days, September 17–18. The second was reported on June 15, 1921, in 14° N. and 81° W. At Cape Mala southerly winds blew for two days, the 16th and 17th, and at Colon for one day, the 16th.

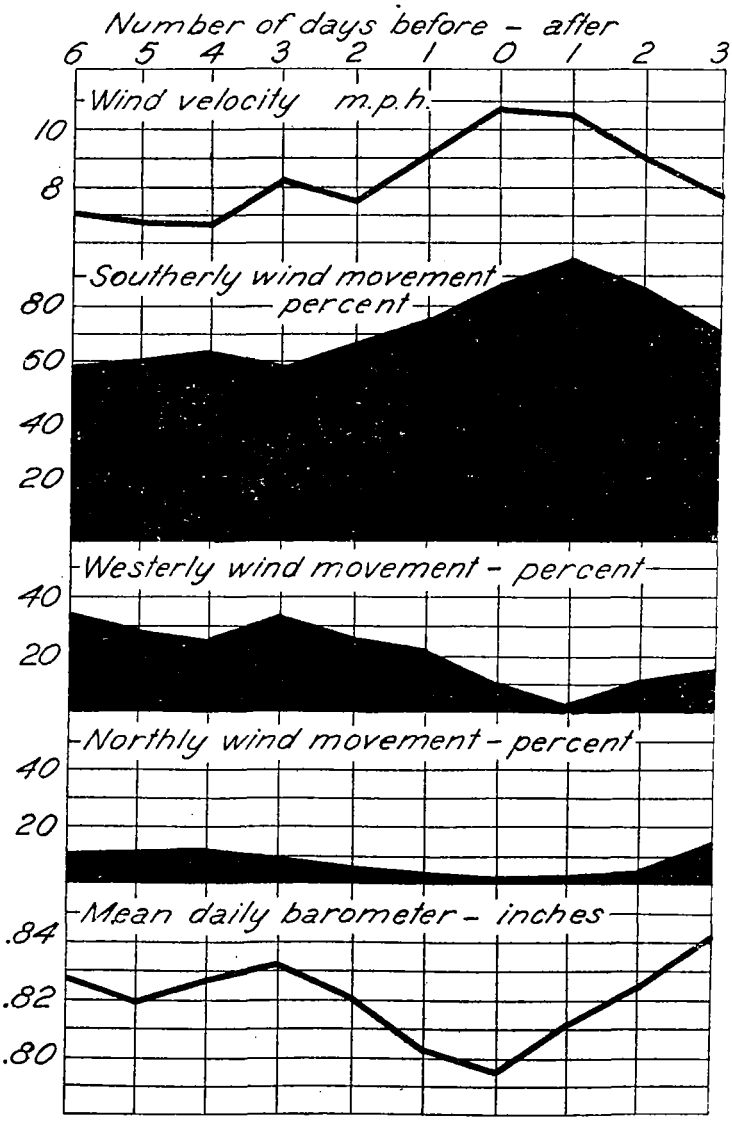

FIG. 10.—Mean daily wind and barometer at Colon for 10-day period at time of formation of tropical cyclones in western Caribbean south of latitude 15° N.

The third storm was reported on October 21, 1921, in 14° N. and 81° W. At Cape Mala the wind blew constantly from southerly points for seven days, the 18th to 24th, inclusive, with daily means ranging from 14 to 21 miles per hour. At Colon southerly winds obtained for four days, the 18th to 22d, inclusive, with daily means ranging from 7 to 18 miles per hour.

Free-air data at Coco Solo are available during the formation of two tropical cyclones. At the time of the formation of the cyclone of October 17, 1924, in 15° N. and 84° W., observations are available from the 13th to the 18th, and up to the 3,000-meter level. Velocities were light at all levels. The direction at the surface was southeast and south-southeast and mostly south to southwest above 1,000 meters.

Several balloon flights to 1,500 meters are available near the time of formation of the cyclone of October 17, 1926, in 12° N. and 80° W. October 16, at 7 a. m., the wind varied from SE. 8 at the surface to a maximum of S. 31 at 750 meters and SSW. 28 at 1,500 meters. October 18, at 7 a. m., the velocity was SE. 19 at the surface and held at SSE. 34 at the 500, 750, and 1,000 meter levels. By 7 a. m. the 19th the wind had fallen to ESE. 9 at the surface, SE. 26 at 500 meters, and SE. 19 at 1,500 meters.

RELATION BETWEEN SOUTHERLY WINDS AND HURRICANE FORMATION

In a comparison of southerly winds at Colon with the time of hurricane formation it is noted that for storms first reported north of latitude 15° the maximum of southerly winds at Colon usually precedes the first report by one or two days; but for storms originating south of latitude 15°, or within 300 miles of Colon, the maximum usually occurs on the day of reported formation or the day following. In other words, as far as the near-by storms are concerned, a cyclonic circulation actually exists and has been identified as such before the maximum of southerly wind occurs at Colon.

A comparison of all available records at Colon and Cape Mala indicates that the initial momentum of these southerly winds originates somewhere in the South Pacific, and that they extend northward with diminishing velocity, and are entirely independent of the existence of any cyclonic formation, but that the appearance of any pronounced maximum at Colon is dependent upon the development and northward progress of a cyclonic circulation. According to fishermen and turtlers familiar with the southwestern Caribbean, the most obvious feature locally at the time of the formation of a tropical cyclone is frequently the southeast gales that persist, sometimes for several days, after the storm has passed. It would appear that the existence of a following wind in the wake of the moving storm, but distinct from the cyclonic circulation itself, is a reality, and that the influence of this wind in intensifying the already existing southerly winds over the Isthmus of Panama produces the comparatively high velocities which is their most noticeable feature.

THE WEATHER OF 1927 IN THE UNITED STATES

By ALFRED J. HENRY

Tables 1 and 2 below contain the statistics of the two most important climatic elements, temperature and precipitation, for 1927.

Weather Bureau officials have sought for a number of years a method of presenting the climatic statistics of continental United States as a single geographic unit in a more satisfactory manner than is now followed. The difficulty lies in the greatly different physiographic features of the several divisions of the area and the unequal distribution of meteorological stations therein. Readers of the REVIEW will recognize in Tables 1 and 2 the same geographic districts as are carried in Table 1 of the MONTHLY WEATHER REVIEW. It is therefore a matter of the saving of much labor to present in a single table the mean values for the several districts combined in an annual mean. It is granted that the combination of the 21 district means into a single mean is meaning-